Scientific Research Publishing

Advances in Applied Sociology, 2026, 16(3), 193-218
https://www.scirp.org/journal/aasoci
ISSN Online: 2165-4336
ISSN Print: 2165-4328

Who Pays for Climate-Resilient WASH? Supplier Perspectives on Pro-Poor Financing and Adaptation in Rural Cambodia

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How to cite this paper: Pham, L. (2026). Who Pays for Climate-Resilient WASH? Supplier Perspectives on Pro-Poor Financing and Adaptation in Rural Cambodia. *Advances in Applied Sociology*, *16*, 193-218.
https://doi.org/10.4236/aasoci.2026.163013

Received: January 8, 2026
Accepted: March 6, 2026
Published: March 9, 2026

Abstract

Climate change is intensifying risks to water, sanitation, and hygiene (WASH) services in rural Cambodia, raising questions about how climate-resilient services can be delivered equitably and who should finance them. Small-scale private WASH suppliers play a central role in rural service delivery, yet their perspectives are rarely reflected in WASH program design. This study examines how rural Cambodian WASH suppliers understand climate adaptation, financing, and pro-poor provision. Drawing on focus group discussions and a scenario-based preference-ranking exercise, it explores adaptation measures suppliers are willing to deliver, financing instruments they consider acceptable, and how free provision for poor households should be financed. The findings show that suppliers prioritise adaptations aligned with existing capabilities, favour financing arrangements that reduce operational and repayment risk, and support free provision only when costs are covered through public or concessional sources. These results contribute supplier-level evidence to debates on climate-resilient and pro-poor WASH financing.

Keywords

Climate-Resilient WASH, Pro-Poor Financing, Rural Service Delivery, Supplier Perspectives, Climate Adaptation, Rural Cambodia

1. Introduction

Climate change is intensifying risks to water, sanitation, and hygiene (WASH) systems in low-income and climate-vulnerable settings, particularly in rural areas exposed to flooding, drought, and water contamination. While climate-resilient WASH has become a central policy objective, far less attention has been paid to a

critical implementation question: who pays for climate-resilient WASH services for poor households?

In rural Cambodia, WASH services are largely delivered by small-scale private suppliers, including family-run sanitation businesses and small water operators. These suppliers are increasingly expected to provide more resilient services and contribute to pro-poor outcomes, yet they operate under constrained margins, regulated tariffs, volatile demand, and high exposure to climate-related risks. Despite their central role in service delivery, supplier perspectives remain underrepresented in the design of climate-resilient WASH programs and financing mechanisms, which often assume that resilience and equity can be achieved through supplier-led delivery or innovative finance alone.

This paper examines how small-scale rural WASH suppliers in Cambodia understand climate resilience, financing, and equity in practice. Using focus group discussions combined with a scenario-based preference-ranking exercise, it explores which adaptation measures suppliers are willing and able to deliver, which financing instruments they find acceptable, and how free provision of climate-resilient WASH services for poor households should be financed. By centring suppliers' assessments of feasibility, risk, and responsibility, the study highlights where pro-poor climate ambitions align—or clash—with the realities of rural service delivery.

The remainder of the paper is structured as follows. Section 2 reviews the literature on pro-poor climate-resilient WASH finance and risk allocation. Section 3-5 describes the study context, methods, and analytical framework. Sections 6 present findings on adaptation preferences, financing options, and approaches to free provision for poor households. Section 7 synthesises implications for pro-poor programme design and financing pilots, followed by conclusions.

2. Financing Resilient WASH in Low-Income Contexts

Recent research shows that financing water, sanitation, and hygiene (WASH) services—including climate-resilient WASH—continues to rely predominantly on public and concessional sources. The so-called "3Ts" (tariffs, taxes, and transfers), together with direct household contributions, remain the backbone of WASH financing, even as climate change increases the scale and urgency of adaptation needs (Hyde-Smith et al., 2025; Fonseca & Pories, 2017). Despite increasing policy attention to innovative and private financing, most WASH services in low-income contexts remain structurally dependent on public funding and donor support.

At the level of service delivery, evidence from sanitation markets shows that small and family-run enterprises face acute cash-flow constraints and high sensitivity to income and climate shocks, limiting their ability to take on debt or absorb repayment risk without subsidies or guarantees (Pories et al., 2019). Evidence from rural water systems shows that revenue collection approaches strongly shape service sustainability and access, with household demand volatility and user behaviour directly influencing operators' exposure to financial and operational

risk—particularly under conditions of environmental stress (Foster & Hope, 2017).

Blended finance has emerged as an important strategy in the WASH sector to mobilise private capital by combining concessional public finance with non-concessional commercial investment through instruments such as grants, guarantees, technical assistance, and risk-sharing mechanisms. Evidence from recent case studies indicates that blended finance enables public funding to act as risk-taking capital, helping to address structural barriers in WASH markets such as low commercial viability, political interference, and high upfront costs (Tkachenko & Mansour, 2021). These case studies across low- and middle-income countries illustrate a wide range of applications, including household-level WASH loans delivered through microfinance institutions, output-based aid to stimulate sanitation markets, development impact bonds linking investor repayment to verified outcomes, and concessional equity and technical assistance to support small and medium water service providers.

Earlier analyses highlighted that the effectiveness of blended finance in WASH is highly context-dependent, shaped by institutional capacity, local delivery arrangements, and the financial and operational performance of service providers (Fonseca & Pories, 2017). Subsequent evidence from OECD (2019) reinforces these concerns, finding that while blended finance models are increasingly visible, they remain unevenly applied and limited in scale. The OECD further identifies persistent sectoral constraints—including high non-revenue water, weak financial management, limited cost recovery, and operational inefficiencies—that lead commercial investors to perceive water and sanitation utilities as high risk. In this context, guarantees and technical assistance are among the most effective blended finance instruments, supporting improvements in creditworthiness and operational performance and enabling a gradual transition from donor dependence toward more sustainable market-based financing, while off-grid sanitation continues to rely heavily on grant funding.

The expansion of innovative finance has also raised concerns about equity, affordability, and financialisation. In urban sanitation, green bonds and environmental impact bonds have been promoted as climate adaptation tools, yet evidence suggests they have not significantly reduced borrowing costs relative to conventional loans (Hyde-Smith et al., 2025). Moreover, such instruments often transfer costs to households through tariffs, potentially exacerbating inequities, while benefits accrue primarily to investors.

Market-oriented and blended financing instruments in the water and sanitation sector have long been criticised for shifting costs to households through tariffs and user fees, while benefits accrue disproportionately to investors (Bayliss, 2014; Loftus & March, 2016). Recent evidence reinforces and extends this critique. Reis et al. (2024) show that the financialisation of water infrastructure generates socio-spatial inequalities, as investment is increasingly channelled toward areas offering higher economic returns, contributing to residential segregation and uneven ser-

vice quality. Their analysis further finds that water trading and market mechanisms can exacerbate disparities, with speculation and price increases limiting access for lower-income households. Despite sustained policy advocacy for private and blended finance, there is little conclusive evidence that private capital has expanded at scale, raising ongoing questions about whether financialisation meaningfully improves access or instead entrenches inequities in WASH service provision (Reis et al., 2024). Without sustained public subsidies and targeted transfers, the growing financialisation of WASH risks undermining universal access objectives, particularly for poor and marginalised populations (Hyde-Smith et al., 2025).

At the same time, much climate-resilient WASH financing has focused on "hard" infrastructure measures, including flood-proofed latrines, raised pits, and stormwater management (Dickin et al., 2020). While such investments are essential, evidence suggests they are insufficient without complementary "soft" measures such as institutional strengthening, planning, capacity building, monitoring, and behaviour change. Dickin et al. (2020) further emphasise that the effectiveness of climate-resilient WASH interventions depends on feasibility at the point of service delivery, including affordability, supplier capacity, and alignment with existing market and institutional conditions.

Technical adaptations in WASH deliver sustained and equitable outcomes only when embedded within broader systems of maintenance, community engagement (Smets et al., 2017). Recent systems-based research reinforces this view. Yasmin et al. (2023) show that WASH resilience and sustainability—particularly in fragile and refugee contexts—depend on integrated service models that align technical infrastructure with institutional coordination, community participation, and long-term operation and maintenance. Similarly, Bosea et al. (2024) demonstrate that persistent WASH challenges in vulnerable regions arise from interlinked technical, social, and governance constraints, requiring whole-of-system approaches beyond infrastructure investment. Reflecting on the sector's evolution, de Wit et al. (2024) emphasise that durable and equitable WASH outcomes ultimately hinge on governance capacity, accountability, and locally embedded service systems.

Emerging opportunities also exist in circular economy and resource-recovery approaches. Investments in energy and nutrient recovery from wastewater have the potential to offset treatment costs and reduce long-term operational expenditure, while contributing to climate mitigation goals (Dickin et al., 2020). Global frameworks such as the GWP-UNICEF Strategic Framework for WASH Climate Resilience and WHO's Sanitation Safety Planning guidelines provide structured pathways for integrating climate risks into WASH policy and planning. Yet translating these frameworks into practice depends on local capacity, financing arrangements, and incentives at the point of service delivery.

Country-level experiences highlight both the promise and limitations of climate-resilient WASH financing. In Cambodia's Svay Rieng Province, rural house-

holds rely heavily on groundwater and rainwater while facing increasing exposure to floods and droughts. Communities prioritise investments in small-scale piped systems, wells, rainwater harvesting, and household-level filtration, alongside non-infrastructure support such as training and maintenance to sustain functionality over time (Hak et al., 2023). Recent national-level analysis reinforces these findings. The UNICEF *Climate Rationale for WASH Services in Cambodia* documents how recurring climate hazards—including floods, droughts, and heat stress—are increasingly undermining WASH infrastructure and service reliability, with basic service gains often lost during climatic shocks (United Nations Children's Fund, 2024: pp. 5-9). Importantly, the report underscores that climate-resilient outcomes depend not only on capital investment but on how financing mechanisms support ongoing operation, maintenance, and institutional capacity, including predictable public subsidies, climate-informed planning, and targeted support for vulnerable communities. Where financing is short-term, fragmented, or overly reliant on household contributions, adaptive capacity remains uneven, reinforcing existing inequalities and leaving poorer and more remote households disproportionately exposed to climate risk (United Nations Children's Fund, 2024: pp. 18-22).

Comparative evidence from low- and middle-income countries illustrates divergent trajectories in integrating WASH within climate finance frameworks. In Bangladesh, recent climate finance mapping shows increasing alignment between national climate strategies and WASH adaptation priorities, supported through climate trust funds and more coordinated planning, suggesting progress in embedding WASH within climate-resilient financing architectures (Anwar et al., 2025). By contrast, global analyses indicate that climate adaptation finance remains a relatively small share of total climate finance and is unevenly distributed, with many least-developed countries—particularly in sub-Saharan Africa—continuing to face structural challenges in prioritising WASH within climate finance portfolios (Global Center on Adaptation, 2024). These patterns point to persistent gaps in national WASH financing strategies, which limit alignment between funding sources and sector priorities and often result in scarce public resources being concentrated in urban areas or used primarily to de-risk private investment, rather than addressing rural access and equity needs (Pories et al., 2019).

The literature highlights a persistent tension between large-scale climate finance mechanisms and local WASH delivery realities. Global instruments such as the Green Climate Fund, the Adaptation Fund, and blended finance vehicles can mobilise substantial capital, yet often struggle to reach vulnerable communities due to bureaucratic complexity, slow disbursement, and limited subnational implementation capacity (Hyde-Smith et al., 2025; United Nations Children's Fund, 2024; Global Center on Adaptation, 2024). Country-level evidence shows that even where climate finance frameworks exist, weak institutional coordination and constrained local access limit alignment with WASH priorities (Anwar et al., 2025). In contrast, locally led and community-based adaptation practices are typ-

ically better targeted to lived vulnerability but remain underfunded, constraining their ability to scale or endure (Hak et al., 2023).

Cambodia illustrates how these dynamics intersect in practice. Donor-supported initiatives under the Cambodia Climate Change Alliance have financed wells, rainwater systems, and latrines, yet evaluations reveal persistent equity gaps. The poorest households are frequently excluded due to labour constraints, competing livelihood priorities, and limited financial and technical support, with beneficiary selection criteria sometimes privileging sustainability over inclusion (Pichdara et al., 2022). At the same time, Cambodia's experimentation with blended and results-based mechanisms, demonstrates the potential for innovative financing to deliver rapid gains, while raising questions about long-term sustainability and equity.

Cambodia-specific evidence highlights that financial risks in rural WASH are disproportionately borne by small-scale suppliers, whose limited margins, regulated tariffs, and exposure to climate-related cost escalation significantly constrain their capacity to absorb debt, manage repayment risk, or cross-subsidise services for poor households (Pham, 2023). Overall, the literature points to a critical gap. While financing frameworks for climate-resilient WASH have become increasingly sophisticated, there is limited practice-based evidence on how small-scale rural suppliers—who play a central role in service delivery—respond to these approaches. In particular, little is known about which adaptation measures suppliers are willing and able to deliver, which financing instruments they find acceptable under climate risk, and how they believe free provision for poor households should be financed. Addressing this gap is essential for designing climate-resilient WASH financing approaches that are not only innovative, but also feasible, equitable, and grounded in the realities of rural service delivery in under-resourced contexts such as Cambodia.

3. The Study

Despite the growing literature on financing climate-resilient WASH, there is limited empirical evidence on how small, rural WASH suppliers perceive climate-resilient products, financing options, and equity obligations in practice. This gap is particularly salient in rural Cambodia, where service delivery depends on small-scale water operators and sanitation businesses that face high climate exposure, constrained margins, and limited access to affordable finance. To address this gap, this pilot study examines three exploratory research questions focused on small-scale WASH suppliers in rural Cambodia:

Q1. Which climate adaptation measures suppliers rank highest under climate stress;

Q2. Which financing instruments they prefer, and whether preferences differ between water and sanitation suppliers; and

Q3. How acceptable free provision of adaptive WASH services to poor households is, and who suppliers believe should finance it.

The study used structured focus group discussions incorporating a scenario-based preference-ranking exercise administered in a survey format to elicit suppliers' assessments of feasibility, risk, and responsibility under increasing climate variability. It forms part of a broader research study on climate change and WASH in rural Cambodia and provides practice-oriented evidence to inform program design and financing pilots. The research was conducted under authorised institutional arrangements in Cambodia. Participation was voluntary, informed consent was obtained, and confidentiality was assured. In line with national requirements, external ethics committee approval was not required.

4. Analytical Framework

This study applies a risk- and feasibility-oriented analytical framework to examine how small-scale rural WASH suppliers understand climate adaptation, financing, and equity in practice. The framework guides interpretation of focus group discussions, within which a scenario-based preference-ranking exercise was embedded as a facilitation tool to prompt reflection, comparison, and discussion. The ranking exercise is not experimental; rather, it supports the focus groups by eliciting suppliers' relative priorities and constraints under conditions of climate stress.

The framework draws on evidence that rural WASH suppliers in Cambodia operate under intersecting pressures related to climate variability, rising operating costs, affordability constraints, and limited access to affordable finance (Pories et al., 2019; Dickin et al., 2020; Pham, 2023; Hyde-Smith et al., 2025). Supplier preferences are therefore interpreted as pragmatic responses to risk, shaped by existing business models, institutional arrangements, and prior engagement with donor and government programs.

Climate risk and adaptation feasibility (***RQ***1)

The first research question examines which climate adaptation measures suppliers prioritise under climate stress. Prior studies show that small rural WASH suppliers tend to favour incremental adaptations that align with existing technical capabilities and market practices, rather than unfamiliar or capital-intensive innovations (Dickin et al., 2020; Hak et al., 2023; Pham, 2023). In the focus groups, suppliers discussed how flooding, drought, and water-quality variability affect service reliability, costs, and customer trust. The embedded ranking exercise prompted suppliers to compare adaptation options relevant to their service models, allowing discussion to surface how climate exposure and business realities shape perceived feasibility.

Cost structure, financing risk, and instrument choice (***RQ***2)

The second research question focuses on suppliers' financing preferences and differences between water and sanitation providers. The literature highlights contrasting risk profiles: water operators face higher capital intensity, longer payback periods, and tariff constraints, while sanitation suppliers operate with lower capital requirements, but face pronounced demand volatility and affordability risk (Pories et al., 2019; Pham, 2023). Across focus group discussions, suppliers re-

flected on repayment risk, collateral requirements, and prior experiences with donor and government programmes. The ranking exercise was used to structure discussion around different financing instruments, helping to reveal tolerance for financial risk and institutional complexity across supplier types (International Water Centre & Lean Finance, 2022).

***Equity, affordability, and responsibility for free provision* (*RQ*3)**

The third research question examines suppliers' views on free provision of climate-resilient WASH services to poor households and responsibility for financing it. Existing evidence indicates that informal cross-subsidisation by small suppliers is rarely sustainable, particularly in climate-vulnerable and low-income contexts (Pories et al., 2019; Pham, 2023; Hyde-Smith et al., 2025), even as equity-oriented adaptation frameworks emphasise the necessity of free or highly subsidised provision for the poorest (Dickin et al., 2020). Within the focus groups, suppliers discussed affordability constraints, moral obligations, and financial limits. Two linked preference questions were used to distinguish between normative support for free provision and views on who should bear the cost, enabling analysis of how equity goals are negotiated in practice.

Across all three research questions, findings from the ranking exercise are interpreted in conjunction with focus group discussion, treating preferences as indicators of relative feasibility and acceptability rather than causal effects. This analytical framing enables the study to generate practice-relevant insights into how small rural WASH suppliers navigate climate adaptation, financing, and equity, directly addressing gaps in supplier-level evidence on climate-resilient WASH delivery in low-income, high-risk contexts.

5. Methods

5.1. Data Collection

Guided by the analytical framework described above, the study employed focus group discussions as the primary method to examine suppliers' experiences of climate risk, financing, and equity in practice. A scenario-based preference-ranking exercise, administered in a survey format, was embedded within each focus group to support comparison and prompt discussion, rather than to generate standalone survey data. This design enabled the study to capture suppliers' feasibility judgements and priorities within the context of real-world service delivery.

Suppliers were asked to rank options across four preference areas:

(1) Climate-resilient WASH products they would be most likely to provide under climate stress. Options were tailored by supplier type and included bottled water distribution (suppliers sell treated drinking water in containers to households), community rainwater harvesting (suppliers invest in a shared rooftop collection and storage systems in their operational area), pumped water supply (suppliers sell water via small-scale piped water systems owned and operated by them), household water filters (point-of-use treatment devices sold to households), resilient latrines built on or above the house (suppliers install elevated or flood-re-

sistant sanitation structures in households for a fee), and HandyPod sanitation systems (suppliers install modular, portable, above-ground toilet units suitable for flood-prone areas for a fee).

(2) Financing instruments considered acceptable and feasible to support delivery. These included government loans (suppliers access public-sector credit and repay the loan over defined period of time), government-guaranteed commercial loans (suppliers access and repay bank loans backed partially by government guarantee), commercial loans without guarantees (suppliers access and repay market-rate loans), credit enhancement mechanisms (suppliers access and repay finance via risk-sharing arrangements that reduce borrowing constraints), government subsidies (suppliers receive non-repayable financial support from the government), donor grants or technical assistance (suppliers receive non-repayable external funding or advisory support), green bonds (suppliers raise capital through environmentally themed debt instruments and repay investors upon the bond maturity), and social impact bonds (suppliers raise capital through performance-based debt instruments and repay investors upon verified outcomes).

(3) Whether climate-resilient WASH services for poor households should be provided free of charge, with response options of yes, no, or not sure.

(4) Responsibility for financing free provision, with suppliers ranking alternative cost-sharing arrangements, including supplier-only contribution, supplier - government co-contribution, supplier - community - government co-contribution, and donor or philanthropic financing.

At the start of each focus group, suppliers collectively identified the most prevalent hazards affecting their operations over the past decade: intense rainfall, drought, storms, flooding, and rising temperatures. Drought was consistently ranked as the most concerning hazard, followed by storms and intense rainfall. Suppliers were then asked to rank WASH adaptation products and financing options under conditions of continued exposure to these hazards. No fixed future time horizon was imposed; instead, the scenario reflected ongoing climate variability based on recent experience.

In the Cambodian rural context, suppliers would receive capital—repayable (loans, bond-financed lending) or non-repayable (grants, subsidies)—or technical support to invest in climate-resilient WASH. Obligations differ by instrument: repayment of principal and interest (loans), performance delivery (social impact bonds), or no repayment (grants/subsidies). This ranking exercise was intentionally framed at a general level to assess relative acceptability of instrument types rather than detailed contractual terms (e.g., collateral, repayment schedules, risk-sharing). More specific design features will be developed and tested in subsequent pilot financing models.

Each adaptation product and financing instrument was presented using illustrated cards (in Khmer) displaying a picture and short description. The cards were placed on a poster board and used to facilitate the ranking and discussion. Rankings were collected individually where every supplier was provided with a paper

survey containing the ranking questions. Suppliers completed the ranking tasks independently to ensure that preferences reflected individual assessments rather than negotiated group positions.

Following completion of the individual ranking survey, suppliers were invited to discuss their rankings collectively within the focus group. This discussion allowed suppliers to explain their reasoning, constraints, and trade-offs, providing qualitative context to support interpretation of the ranking data. The qualitative discussion was analysed alongside the descriptive statistics of ranking data to strengthen understanding of feasibility perceptions and risk considerations.

5.2. Focus Group Implementation and Validity Considerations

All focus groups were conducted in Khmer and facilitated by the author, supported by two Cambodian research consultants who acted as interpreters and research assistants. The author designed the ranking survey, which was translated into Khmer by the consultants. Participants completed the paper-based survey individually in Khmer; responses were later translated into English and entered into Qualtrics for data management and descriptive analysis.

Sessions were audio-recorded with consent, transcribed in Khmer, and translated into English. Translation accuracy was verified through joint review to ensure conceptual consistency, particularly for technical and financing terminology.

Supplier participants were recruited through village leaders via invitation letters issued by the Country Director of the local NGO implementing the project. These leaders, who had collaborated with the researcher previously, identified suppliers with direct experience in rural WASH service delivery. To minimise potential influence, invitations emphasised voluntary participation, confidentiality, and the independence of the research from funding decisions. Village leaders did not attend the sessions. Facilitators reiterated that there were no right or wrong answers, and the individual ranking exercise prior to group discussion helped reduce conformity bias.

5.3. Data Analysis

Completed paper surveys were subsequently entered into Qualtrics, where the ranking instrument had been programmed for data capture and analysis. There were no missing responses for the ranking questions; therefore, no imputation or adjustment procedures were required. Descriptive statistics were used to calculate means and standard deviations for each ranked option, with lower scores reflecting stronger preference. The unit of analysis was the individual supplier respondent. Given the small sample size and exploratory design, bootstrapping was used to assess the stability of descriptive statistics rather than to support statistical inference. The bootstrapped estimates were thus used as a robustness check on central tendencies, not as a basis for hypothesis testing or generalisation. As with all small-sample descriptive approaches, bootstrapping does not address selection bias or representativeness, and findings are interpreted as indicative rather than generalisable.

Qualitative data from focus group discussions were analysed thematically using a coding framework aligned with the analytical framing and performed for each RQ. Coding followed three primary domains: (i) preference rationales linked to the ranking exercise; (ii) perceived risks and constraints, including financial, operational, and institutional risks; and (iii) exposure to climate stressors such as flooding, drought, and water-quality variability. This approach enabled integration of ranking outputs with discussion-based explanations, allowing preferences to be interpreted in relation to the suppliers' lived experiences, business models, and risk environments.

5.4. Participants

Three focus groups were conducted in June-July 2023 with small-scale water and sanitation suppliers in rural Cambodia, combining facilitated discussion with a preference-ranking exercise. Approximately 50 suppliers were invited; 23 declined due to time constraints, resulting in 27 participants (6 female). Of these, 18 were sanitation suppliers and 9 were water operators. Table 1 presents the provincial distribution of participants, and Figure 1 maps the seven provinces in which the suppliers operate.

Table 1. Supplier participants and locations.

Provinces	Number of supplier participants
Prey Veng	2 Water operators; 4 Sanitation suppliers. Total: 6
Tbong Khmum	1 Water operator; 1 Sanitation supplier. Total: 2
Takeo	1 Water operator. Total: 1
Kampong Speu	1 Water operator; 1 Sanitation supplier. Total: 2
Pursat	1 Water operator; 8 Sanitation suppliers. Total 9
Kampong Chhnang	1 Water operator. Total: 1
Kratie	1 Water operators; 5 Sanitation suppliers. Total: 6
All provinces	8 Water operators; 19 Sanitation suppliers. Total: 27

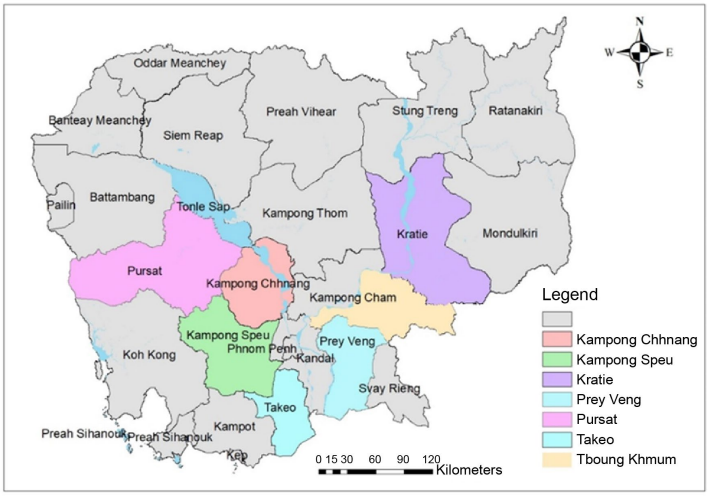

Figure 1. Geographic distribution of supplier participants in Cambodia.

Among the nine water operators, experience levels varied, with around half in business for fewer than six years and a smaller group operating for more than a decade. Formal education levels were generally low, with most operators having primary or lower-secondary education. Nearly all operated in rural areas, and the majority provided piped water services, with a smaller number engaged in bottled water distribution or water filtration. Piped water tariffs are government-regulated and relatively low, limiting revenue flexibility. Monthly revenues varied widely, though several operators declined to disclose income.

Sanitation suppliers were similarly small-scale and predominantly family-run, with limited formal education and workforces typically comprising fewer than ten people. Experience in the sector ranged from early-stage businesses to long-established operators. Most served rural markets, with some extending services to peri-urban areas. Core activities included latrine construction, material sales, and related services, with latrine building as the primary income source. Sales volumes and monthly incomes varied substantially, reflecting heterogeneity in business scale. Suppliers reported multiple climate-related challenges, including hard ground conditions, flooding, and drought, which directly affect construction costs and demand.

Overall, the supplier sample is heterogeneous but predominantly rural and small-scale, characterised by limited formal education, constrained pricing power, and high exposure to climate-related risks. These characteristics provide essential context for interpreting suppliers' preferences regarding adaptation measures, financing options, and approaches to pro-poor service provision.

6. Results and Discussion

6.1. RQ1. Which Climate Adaptation Measures Ranked Highest under Climate Stress?

The preference-ranking exercise, interpreted alongside focus group discussions, reveals clear and internally consistent patterns in how suppliers prioritise climate adaptation measures, with distinct preferences across water operators and sanitation suppliers.

As shown in Table 2, water operators ranked bottled water distribution systems as the most preferred adaptation option under climate stress, followed by household water filters. Community rainwater harvesting ranked lower, while pumping services were consistently ranked lowest. Focus group discussions indicate that these preferences reflect operators' experience of increasing operational challenges linked to flooding, water contamination, and seasonal variability.

Water operators reported that heavy rains and flooding introduce polluted surface water from agricultural runoff, increasing turbidity and contamination and requiring additional chemical treatment, labour, and electricity. Muddy water was reported to damage filtration systems and increase pumping costs, while flooding also raised the incidence of pipe breakages. Coping strategies included sandbagging storage tanks, raising pumps and electrical devices, and closely monitoring

electricity use—measures that increase operating costs and labour demands.

During dry periods, operators, who were reliant on tube wells, described problems with manganese and lime contamination, requiring either additional treatment or sourcing water from other operators. One operator explained:

"We helped transfer water from the stream to sell to them. One tank of 2,000 litres costs from USD 10 to 12.50… where possible, we asked our partnered NGO to drill a well or dig a pond." (Water operator, Pursat)

Seasonal demand fluctuations further shaped preferences. Operators noted that during the rainy season, many households switch to rainwater for drinking, reducing demand for piped water. Cultural perceptions were reported to influence these choices:

"Some people felt that pipe water is less clean than rainwater, so they use pipe water for washing clothes and animals, and collect rainwater for drinking." (Water operator, Prey Veng)

Within this context, bottled water and filtration technologies were perceived to be more reliable and marketable options during climate stress, while pumping services were viewed as offering limited additional value because most households already rely on their own tube wells until these are exhausted.

Sanitation suppliers ranked resilient latrines built on or above the house as the most preferred adaptation measure, followed by HandyPod systems, while options outside their core business were ranked lower (Table 2). Focus group discussions revealed that flooding damages latrines and increases demand for more resilient designs, while droughts reduce household purchasing power and delay sanitation investments. Suppliers reported that hard ground conditions during droughts and flooding during the wet season increase labour requirements and construction costs, reinforcing preferences for adaptation measures aligned with existing construction practices and supply chains.

Table 2. Supplier preferences for climate-resilient WASH adaptation measures under climate stress.

Adaptation measure	Water suppliers Mean (SD)	Sanitation suppliers Mean (SD)
Bottled water distribution system	1.63 (0.39)	—
Resilient latrine (on the house)	—	1.53 (0.17)
HandyPod system	—	2.24 (0.27)
Water filter	2.63 (0.39)	3.18 (0.22)
Community rainwater harvesting	2.75 (0.34)	—
Water pump or water pumping service	3.00 (0.25)	3.06 (0.20)

Notes to the table: Rankings are based on the preference-ranking exercise embedded within focus group discussions; Lower mean scores indicate higher preference; "—" indicates options not presented to that supplier group.

These findings align closely with the analytical framework for RQ1, which con-

ceptualises adaptation preferences as risk-management responses shaped by climate exposure, cost structures, and market feasibility, rather than technological novelty. Consistent with prior research, these small-scale suppliers in low-income and climate-vulnerable settings favour incremental and familiar adaptations constrained by operating margins, institutional context, and user behaviour (Adger et al., 2009; Dickin et al., 2020; Yasmin et al., 2023; de Wit et al., 2024).

To tighten integration between the ranking results and qualitative findings, **Table 3** summarises the core coding outputs used to interpret adaptation preferences. Codes were developed around climate exposure impacts, operating cost pressures, revenue volatility, household behaviour, and affordability constraints. These mechanisms explain why incremental, business-aligned adaptations were prioritised over more capital-intensive or unfamiliar options.

Table 3. Summary of core coding outputs for RQ1.

Coding category	Mechanism interpreting ranking	Illustrative quote	Link to ranking pattern
Increased treatment costs under heavy rainfall	Climate stress increases chemical, labour, and electricity costs, favouring controllable treatment options	"When there is raining or plowing, our stream is really dirty. It costs us more and consumes our time."	Explains higher ranking of bottled water and filtration
Quality and reputational risk	Operators seek options that protect consumer trust under contamination risk	"When water becomes so dirty, I need to mix the PAC… at least 2 to 3 times… I need to add lime as well."	Supports preference for filtration over pumping expansion
Seasonal revenue volatility	Rainwater substitution reduces piped water demand during rainy season	"I normally earn 10,000$ but was reduced to 5,000$… only happened in the rainy season."	Explains low ranking of expanded pumping services
Household reliance on self-supply	Households exhaust tubewells before connecting to network supply	"They pump their tubewells until they are completely dried. Only then they will connect to our network."	Reinforces limited demand for pumping adaptation
Flood damage to sanitation infrastructure	Flooding increases need for elevated and adjustable latrine designs	"I was requested to raise the platform, add up the ring, and fix the existing pipe."	Explains high ranking of resilient latrines and HandyPod
Price sensitivity and affordability constraints	Adaptations must align with household ability to pay	"The price of adjusting to the twin pit latrine is 105$ which is similar to rebuilding the new substructure."	Supports preference for incremental sanitation adjustments

Taken together, the coded qualitative evidence clarifies the mechanisms underlying the ranking results. For water operators, the preference for bottled water and filtration reflects strategies to manage quality risk, reputational risk, and revenue volatility under climate stress (Bain et al., 2014; Foster & Hope, 2017; Pham, 2023; Hyde-Smith et al., 2025). The consistently low ranking of pumping services aligns with evidence that rural households rely on self-supplied groundwater until wells fail, limiting willingness to pay for alternative supply while increasing operators' exposure to electricity and infrastructure risks (Hak et al., 2023; Foster & Hope, 2017).

For sanitation suppliers, higher rankings for resilient latrine designs and HandyPod systems reflect income-sensitive demand and the need to minimise construc-

tion and payment risk under climate variability (Jenkins & Scott, 2007; Coffey et al., 2014; Pories et al., 2019; Dickin et al., 2020). These patterns reinforce adaptation scholarship emphasising feasibility, path dependency, and local capacity as central to climate responses, particularly in WASH systems where technical, financial, and institutional constraints shape what adaptations can realistically be delivered and sustained (Adger et al., 2009; Cleaver, 2012; Yasmin et al., 2023; de Wit et al., 2024; Reis et al., 2024).

The combined ranking and focus group findings therefore suggest that climate-resilient WASH adaptation in rural Cambodia is most likely to be adopted when it builds on existing supplier practices, consumer trust, and market norms, rather than assuming uptake of unfamiliar technologies or service models (Dickin et al., 2020; Hyde-Smith et al., 2025). The results also echo political economy analyses cautioning against adaptation strategies detached from delivery realities, particularly where climate finance and resilience agendas are insufficiently aligned with local delivery capacity and equity considerations (Rusca & Schwartz, 2018; Hyde-Smith et al., 2025; United Nations Children's Fund, 2024).

6.2. RQ2. Which Financing Instruments Are Preferred, and Do Preferences Differ by Supplier Type?

The ranking exercise and focus group discussions reveal a clear divergence in financing preferences between water operators and sanitation suppliers, reflecting differences in cost structure, risk exposure, and business models (**Table 4** and **Table 5**).

Water operators consistently ranked donor grants and technical assistance as the most acceptable financing options across adaptation measures, while commercial loans without guarantees and bond-type instruments ranked lowest. Government loans and government-guaranteed commercial loans occupied intermediate positions.

Focus group discussions indicate that these preferences are shaped by rising operating costs, tariff constraints, and exposure to climate-related risks. Operators described how flooding and heavy rains increase treatment costs due to polluted surface water, while muddy water damages filters and increases electricity consumption for pumping. Flooding also increases pipe breakages, forcing costly repairs. During dry seasons, tube-well operators reported manganese and lime contamination, requiring additional treatment or water purchases from other suppliers, often at the expense of profits. As one operator explained:

"We helped transfer water from the stream to sell to them. One tank of 2,000 litres costs from USD 10 to 12.50… where possible, we asked our partnered NGO to drill a well or dig a pond." (Water operator, Pursat)

Governance challenges further compounded these risks. Operators in Kampong Speu described cooperation with local authorities to conserve water, which were undermined by unregulated activities. In Takeo, industrial pollution imposed both treatment costs and regulatory fees:

"There's trash in the lake and it caused a bad odour… we tried using alum, PAC and wood charcoal. The problem is the cost of treatment of the bad odour, and the fee paid to the authority which can be up to USD 5,000-6,250 per year." (Water operator, Takeo)

Within this context, grants and technical assistance were viewed as essential for managing climate risk, while loan-based finance was seen as increasing financial vulnerability. This aligns with evidence that small water utilities in weak regulatory environments rely heavily on concessional finance due to limited capacity to absorb repayment risk (Bouwer & Aerts, 2006; Hyde-Smith et al., 2025).

Table 4. Water operators' preferences for financing instruments by adaptation measure (RQ2).

Financing option	Bottled water distribution	Water filter	Community rainwater harvesting	Water pump/ pumping service
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Government loan	3.24 (0.81)	2.73 (0.74)	3.61 (0.80)	2.75 (0.75)
Commercial loan (government-guaranteed)	4.77 (0.69)	4.87 (0.60)	4.78 (0.61)	4.72 (0.58)
Commercial loan (no guarantee)	5.87 (0.59)	6.23 (0.60)	5.49 (0.63)	6.51 (0.57)
Credit enhancement	4.13 (0.50)	5.51 (0.57)	3.86 (0.57)	4.74 (0.44)
Government subsidies	3.62 (0.73)	3.61 (0.46)	4.48 (0.56)	3.74 (0.45)
Grants/technical assistance (donors)	2.53 (0.63)	1.62 (0.46)	1.51 (0.46)	1.64 (0.48)
Green bonds	6.40 (0.79)	5.75 (0.79)	6.47 (0.72)	5.51 (0.78)
Social impact bonds	5.51 (0.60)	5.60 (0.40)	5.74 (0.57)	6.33 (0.47)

Notes to the table: Rankings are based on a scenario-based preference-ranking exercise embedded within focus group discussions; Lower mean scores indicate stronger preference; Water operators and sanitation suppliers were presented with different adaptation options reflecting their service models; Water operators and sanitation suppliers were presented with the same financing instruments options.

Sanitation suppliers showed comparatively greater openness to government loans and government-guaranteed commercial loans, particularly for resilient latrine construction and related services (Table 5). Focus group discussions indicate that this reflects their need for working capital rather than large infrastructure investment, alongside narrower profit margins and demand volatility. As one supplier noted, droughts reduce household purchasing power and delay sanitation investments:

"When there is drought, people don't think about latrines. They think about water, food, and daily survival. Only when they have extra money do they come back to us." (Sanitation supplier, Kratie)

Smaller, family-run suppliers expressed reluctance to take on unguaranteed commercial loans, citing limited ability to absorb repayment risk, while larger suppliers were more open to loan finance if supported by subsidies or guarantees. These patterns are consistent with studies showing that sanitation enterprises face

acute cash-flow constraints and high sensitivity to climate and income shocks (Pories et al., 2019; Dickin et al., 2020; Pham, 2023).

These patterns align with the analytical framework for RQ2, which conceptualises financing preferences as responses to repayment risk, cost volatility, cash-flow constraints, and climate-linked demand uncertainty, rather than abstract preferences for specific financial instruments (OECD, 2019; Tkachenko & Mansour, 2021; Reis et al., 2024).

Table 5. Sanitation suppliers' preferences for financing instruments by adaptation measure (RQ2).

Financing option	Resilient latrine (on the house)	HandyPod system	Water pump/ pumping service	Water filter
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Government loan	2.18 (0.27)	2.70 (0.35)	2.77 (0.38)	2.81 (0.42)
Commercial loan (government-guaranteed)	2.93 (0.35)	3.05 (0.40)	3.53 (0.41)	3.30 (0.38)
Commercial loan (no guarantee)	4.29 (0.53)	4.52 (0.42)	4.83 (0.56)	4.42 (0.60)
Credit enhancement	4.46 (0.44)	4.87 (0.34)	4.49 (0.42)	4.79 (0.44)
Government subsidies	5.06 (0.29)	3.39 (0.58)	4.53 (0.42)	4.59 (0.41)
Grants/technical assistance (donors)	4.02 (0.61)	6.40 (0.37)	3.43 (0.67)	3.45 (0.65)
Green bonds	6.41 (0.36)	6.30 (0.50)	6.13 (0.37)	6.07 (0.36)
Social impact bonds	6.66 (0.48)	4.70 (0.59)	6.34 (0.49)	6.58 (0.46)

Notes to the table: Rankings are based on a scenario-based preference-ranking exercise embedded within focus group discussions; Lower mean scores indicate stronger preference; Water operators and sanitation suppliers were presented with different adaptation options reflecting their service models; Water operators and sanitation suppliers were presented with the same financing instruments options.

To tighten integration between ranking results and qualitative evidence, **Table 6** summarises the core coding outputs used to interpret financing preferences. Codes were developed around operating cost pressures, seasonal revenue volatility, governance-related cost burdens, working capital constraints, and repayment risk perception under climate stress.

Overall, the results indicate that financing preferences are shaped less by the novelty of instruments and more by suppliers' exposure to climate risk, cost uncertainty, repayment constraints, and the degree to which financing arrangements reduce risk at the point of service delivery rather than shifting it onto small providers (OECD, 2019; Tkachenko & Mansour, 2021; Reis et al., 2024). The strong divergence between water operators and sanitation suppliers reflects fundamental differences in capital intensity, revenue structure, and risk-bearing capacity. For water operators, high capital intensity, rising operating costs, tariff constraints, and revenue volatility combine to make debt-financed investment particularly risky. Prior studies show that small water utilities in low-income contexts face increasing operating expenditures under climate stress, while weak regulatory environments and limited tariff flexibility constrain cost recovery (Bouwer & Aerts,

2006; Hyde-Smith et al., 2025). In such settings, concessional finance, grants, and technical assistance reduce downside risk and provide flexibility that commercial loans or bond-based instruments do not. The strong preference for donor-supported and concessional finance observed in this study is therefore consistent with recent evidence that small WASH providers rely on public and concessional support when exposure to climate risk, operating cost volatility, and governance constraints limits their ability to absorb repayment risk (Pham, 2023; OECD, 2019; Tkachenko & Mansour, 2021; Hyde-Smith et al., 2025).

Table 6. Summary of coding outputs for RQ2.

Coding category	Mechanism interpreting ranking	Illustrative quote	Link to ranking pattern
Rising treatment and operating costs under climate stress	Cost volatility reduces ability to absorb repayment obligations	"When there is raining or plowing, our stream is really dirty. It costs us more and consumes our time."	Explains water operators' strong preference for grants and low preference for commercial loans
Seasonal revenue volatility	Rainy-season profit losses increase repayment risk	"I normally earn 10,000$ but was reduced to 5,000$… only happened in the rainy season."	Supports resistance to unguaranteed commercial loans
Governance and regulatory cost burdens	Compliance and treatment fees reduce financial buffer	"The problem is the cost of treatment of the bad odour, and the fee paid to the authority which can be up to USD 5,000 - 6,250 per year."	Reinforces preference for concessional finance
Working capital constraints (sanitation enterprises)	Need liquidity to extend credit and support subsidy-linked sales	"Most of my money was buried in the subsidy program… I wish to have more money so I can lend to the poor."	Explains openness to government-backed loans
Climate-sensitive household demand	Income shocks delay sanitation investment	"When there is drought, people don't think about latrines… Only when they have extra money do they come back to us."	Supports preference for risk-shared loan mechanisms rather than commercial debt

Sanitation suppliers' comparatively greater openness to loan-based finance reflects a distinct position within the rural WASH economy and contrasts sharply with water operators' resistance to debt financing. While sanitation enterprises operate with lower capital intensity than water utilities, they face pronounced demand volatility and ongoing cash-flow constraints, particularly under climate stress. As Pham (2023) observed, financial risks in rural WASH are disproportionately borne by small-scale providers, many of whom lack the capacity to absorb repayment shocks or finance expansion under conditions of climate and demand uncertainty.

These constraints are compounded by lending conditions that are poorly aligned with WASH service delivery, including collateral requirements, high interest rates, and short loan tenors that do not match the long-term nature of water and sanitation investments (International Water Centre & Lean Finance, 2022). Within this context, sanitation suppliers' preference for government-guaranteed or subsidised loans reflects a need for accessible and predictable working capital with

risk-sharing, rather than a willingness to assume commercial debt. This pattern is consistent with evidence from Cambodia and other low-income settings, which identifies working capital constraints and income sensitivity as key barriers to scaling small-scale sanitation enterprises (Pories et al., 2019; Dickin et al., 2020).

Across both supplier groups, the consistently low ranking of green bonds and social impact bonds reinforces the framework's expectation that complex or financialised instruments are poorly aligned with the realities of small rural enterprises. As argued in the literature, such instruments often fail to reduce risk at the point of service delivery and may increase transaction costs without improving affordability or feasibility for local providers (Hyde-Smith et al., 2025; Rusca & Schwartz, 2018). These findings suggest that climate-resilient WASH financing must be differentiated by supplier type and grounded in supplier-level feasibility, rather than assuming a single financing pathway can effectively support both water and sanitation providers.

6.3. RQ3. How Acceptable Is Free Provision to Poor Households, and Who Should Finance It?

Across both water operators and sanitation suppliers, the preference-ranking exercise showed strong support for the principle of providing climate-resilient WASH services free of charge to poor households. When asked whether such services should be provided free of charge to poor households, 26 of the 27 suppliers responded affirmatively, while one water operator indicated uncertainty.

However, preferences shifted markedly when suppliers were asked to rank who should finance free provision (Table 7). Across both supplier groups, arrangements in which suppliers alone bore the cost were ranked lowest. By contrast, donor or philanthropic financing was ranked as the most acceptable option, while shared cost arrangements involving government were consistently preferred over supplier-only financing.

Table 7. Supplier preferences for financing free provision of climate-resilient WASH services to poor households.

Financing arrangement for free provision	Water suppliers Mean (SD)	Sanitation suppliers Mean (SD)
Supplier contributes alone	3.50 (0.37)	3.06 (0.20)
Supplier and government co-contribute	2.88 (0.28)	2.24 (0.27)
Supplier, NGOs, and government co-contribute	2.12 (0.11)	3.18 (0.22)
Donors or philanthropic organisations contribute	1.51 (0.36)	1.53 (0.17)

Notes to the table: Rankings are based on a scenario-based preference-ranking exercise embedded within focus group discussions; Lower mean scores indicate stronger preference.

These findings align with the analytical framework for RQ3, which distinguishes between normative support for equity goals and the allocation of financial

risk and responsibility in achieving those goals. To clarify the mechanisms underlying this divergence, Table 8 summarises the key coding outputs for RQ3.

Table 8. Summary of coding outputs for RQ3.

Coding category	Mechanism interpreting ranking	Illustrative quote	Link to ranking pattern
Normative commitment to universal sanitation	Equity seen as moral and public health imperative	"First, make sure that everyone has a toilet."	Explains near-unanimous support for free provision in principle
Recognition of extreme poverty	Some households cannot contribute at all	"Can subside some, but better just give them for free because they are very poor."	Supports strong endorsement of full subsidy for poorest
Supplier financial constraints	Small enterprises cannot absorb subsidy burden	"For sanitation suppliers, we don't have much cash to maintain cash flow."	Explains rejection of supplier-only financing
Dependence on NGO/government ecosystem	Free provision historically enabled by NGO support	"Without NGOs support, seem like they never make it to reach to the grass root demand."	Explains preference for donor or shared public financing
Governance and fairness concerns	Subsidy targeting sometimes politicised or misallocated	"Some real poor families did not receive the grant."	Explains preference for transparent external financing
Capacity and planning gaps at local government level	Weak implementation capacity limits predictable cost-sharing	"They should have a good habit of preparing such a plan for the people."	Reinforces preference for donor-led or structured co-financing

The qualitative evidence clarifies the distinction between normative endorsement of equity and rejection of supplier-funded cross-subsidisation. Suppliers emphasised that while free or heavily subsidised provision is necessary for poor households—particularly under climate stress—they lack the financial capacity to absorb these costs without external support. Sanitation suppliers were explicit about this constraint:

"We can't give free latrines because we also need to cover our costs. If the government or NGOs share the cost, then we can help the poor." (Sanitation supplier, Kampong Speu)

Suppliers also noted that poor households are least able to pay for resilient WASH services precisely during droughts or floods, when immediate survival needs take priority. However, this moral endorsement did not translate into willingness to absorb costs individually. Suppliers emphasised their limited margins and working capital constraints. Even where start-up costs were modest for sanitation businesses, liquidity remained tight, and free provision without cost-sharing was financially unviable. Suppliers repeatedly highlighted reliance on NGO programmes and subsidy schemes to reach poor households. One supplier noted that without NGO support, WASH programmes struggle to reach grassroots demand. At the same time, concerns about misallocation of "ID Poor" benefits and local-level discrimination underscored the need for transparent and accountable financing mechanisms (Pham 2023).

These findings reflect well-documented constraints in rural WASH markets,

including limited margins, high exposure to climate-related cost escalation, weak capacity for cross-subsidisation, and increasing risks associated with the financialisation of service delivery under climate stress (Pories et al., 2019; Pham, 2023; Hyde-Smith et al., 2025; Reis et al., 2024). The preference for donor-funded or government-supported models is consistent with recent evidence that free provision in low-income and climate-vulnerable contexts is rarely sustainable without explicit public or concessional financing arrangements that prevent the costs of climate adaptation being transferred to small suppliers or poor households (Rusca & Schwartz, 2018; Hyde-Smith et al., 2025; United Nations Children's Fund, 2024; Reis et al., 2024). Hyde-Smith et al. (2025) similarly cautioned that shifting the costs of climate adaptation onto suppliers or households' risks deepening inequities rather than resolving them.

For sanitation suppliers in particular, shared financing arrangements reflect the interaction between income-elastic demand and climate stress. As documented in Cambodia and other low-income settings, sanitation investments are often postponed during periods of economic or climatic shock, making supplier-funded free provision especially risky (Dickin et al., 2020; Pories et al., 2019).

Overall, the RQ3 findings reinforce the framework's core proposition that equitable climate adaptation in WASH depends not only on recognising the need for free provision, but on explicitly allocating responsibility for financing it. Suppliers' preferences indicate that climate-resilient WASH services for poor households are most feasible when financed through public and concessional sources, rather than through supplier-funded cross-subsidisation (Dickin et al., 2020; Hyde-Smith et al., 2025).

7. Implications for Climate-Resilient WASH Policy and Practice

The findings highlight several implications for the design and financing of climate-resilient programs in low-resource and high-risk contexts from the perspective of small-scale rural Cambodian WASH suppliers. First, financing should prioritise supplier-ready adaptation measures - options that align closely with existing products, skills, and delivery models. Framing resilience around what suppliers can realistically deliver under climate stress increases the likelihood of uptake and reduces the gap between policy ambition and everyday service provision.

Second, financing approaches need to be differentiated by supplier type, reflecting distinct risk exposures and business models. From suppliers' perspectives, grant- and technical assistance-led pathways are more suitable for water operators facing high capital intensity and tariff constraints, while concessional or government-guaranteed credit is more appropriate for sanitation suppliers requiring working capital under volatile demand. Testing parallel financing pathways prior to scale-up can help ensure instruments match supplier realities.

Third, suppliers strongly supported making climate-resilient WASH services free for poor households, but only where financing responsibilities are clearly al-

located beyond the supplier. From a supplier perspective, mixed financing models—combining donor resources, public subsidies, and targeted climate funds—are more feasible than informal cross-subsidisation by small enterprises. Explicit targeting of poor and climate-vulnerable households is therefore essential.

Finally, suppliers' preferences caution against over-reliance on complex or highly financialised instruments. Simple risk-reduction tools—such as concessional lending, partial guarantees, credit enhancement, and bundled technical assistance—are better aligned with how rural suppliers assess risk and feasibility. Pairing finance with practical business and risk-management support is likely to improve both uptake and sustainability.

An implementable pilot could test two differentiated financing tracks aligned with supplier type, alongside a structured mechanism for financing free provision to poor households. For water operators, a grant-plus-technical assistance package could support climate-specific capital upgrades (e.g., elevated pumps, backup storage, flood protection, treatment improvements), combined with time-bound operational and maintenance (O&M) risk support during extreme events (e.g., chemical or water-transfer cost spikes). Grants could cover approximately 40%-60% of verified climate-resilience capex and be bundled with mandatory technical assistance on water quality management, energy efficiency, hydraulic design, and financial planning to reduce operational risk.

For sanitation suppliers, a government-guaranteed working capital facility could provide loans of USD 500-5,000 with 24-36 month tenors, a 3-6 month grace period aligned with seasonal sales cycles, and a 50%-70% partial credit guarantee to reduce collateral requirements. This facility would be paired with basic business support (cash-flow management, subsidy coordination, record keeping) and linked to participation in pro-poor targeting schemes.

To operationalise suppliers' strong support for free provision, the pilot should include a dedicated subsidy window for poor and climate-vulnerable households, financed through donor and/or public funds rather than supplier cross-subsidisation. Subsidy allocations would be pre-defined, transparently targeted, and disbursed directly to suppliers upon verified installation, ensuring that equity goals are achieved without transferring financial risk to small enterprises. Testing these parallel pathways over 18-24 months would allow evaluation of repayment performance, service expansion, climate-resilience outcomes, and equity impacts before scale-up.

8. Conclusion

This exploratory study provides grounded evidence on how small-scale rural WASH suppliers in Cambodia understand climate resilience through everyday delivery, financing, and equity decisions. Across adaptation choices, financing preferences, and views on free provision, suppliers consistently framed resilience as a matter of feasibility and risk management, rather than technological novelty or financial innovation. Suppliers prioritised adaptation measures aligned with existing prod-

ucts and capabilities, favoured financing arrangements that reduced exposure to repayment and operational risk, and supported equity-oriented free provision only where costs were borne through public or concessional sources rather than by suppliers themselves.

These patterns highlight persistent misalignments between global climate-finance narratives and the realities of rural WASH service delivery. For small suppliers operating under climate stress, limited margins, and volatile demand, resilience is most achievable when interventions align with existing business models, risk-sharing mechanisms, and locally trusted delivery pathways. The findings therefore reinforce the need for climate-resilient WASH strategies that are differentiated by service type and grounded in supplier-level feasibility, rather than assuming uniform uptake of innovative technologies or financing instruments.

The study has several limitations. It draws on a small and heterogeneous sample across multiple provinces, limiting statistical generalisability and suggesting that preferences may vary by location, season, and market conditions. While bootstrapping was used to improve the robustness of descriptive estimates given the small sample size, this approach does not address selection bias or substitute for causal inference. In addition, the scenario-based ranking exercise captures stated preferences rather than observed behaviour, which may change when suppliers face actual financing terms, supply constraints, or shifts in household demand. The findings should therefore be interpreted as indicative rather than definitive.

Despite these limitations, the study demonstrates the value of learning-by-doing approaches in rural WASH adaptation. By combining focus group discussions with a scenario-based preference-ranking exercise, this study adds practice-oriented empirical insight into how small rural WASH suppliers prioritise climate adaptation, financing, and free provision in Cambodia. It addresses a critical gap in the literature, which has largely overlooked supplier perspectives despite their central role in delivering climate-resilient and pro-poor WASH services. Future pilots, such as those described in the previous section, can build on this work by generating practice-based evidence through systematic tracking of a focused set of supplier-oriented indicators: (i) which adaptation measures are delivered at scale; (ii) which financing instruments are taken up and sustained; and (iii) how effectively free provision or subsidies reach poor and vulnerable households. Such an approach can help ensure that climate-resilient WASH initiatives remain both operationally feasible and equity-oriented, while progressively strengthening the evidence base needed to support adaptation in rural, under-resourced contexts similar to Cambodia.

Acknowledgements

The author thanks the two Cambodian research consultants who supported data collection for this study, including translation, facilitation assistance, and transcription.

Funding

This study was funded by the Australian Department of Foreign Affairs and Trade under Water for Women Fund, grant number WIIG08.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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